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of a Pilot Interface  
With an Automatic  
Terminal Approach System**

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Hampton, Virginia*



National Aeronautics  
and Space Administration

**Scientific and Technical  
Information Branch**

## Summary

A piloted-simulation study was performed to evaluate the pilot interface with an automatic terminal approach system (ATAS). The ATAS was conceived as a concept for improving the pilot interface with high levels of automation. It consists of instrument approach data storage, automatic radio tuning, autopilot, autothrottle, and annunciation of flight status. These components allow the ATAS to automatically execute instrument approaches, including procedure turns, altitude changes, missed approaches, and holding patterns, without requiring the pilot to set up navigation radios or change autopilot modes.

The results show that fewer pilot blunders were made during approaches when using the ATAS than when using a baseline, heading-select autopilot. With the baseline autopilot, blunders tended to involve loss of navigational situational awareness or instrument misreading, while with the ATAS, blunders tended to involve a lack of awareness of the ATAS mode state. The ATAS display provided adequate approach-status information to maintain navigational situational awareness, and a side-task measure did not show any significant difference in pilot work load between the two levels of automation.

## Introduction

General aviation instrument flight rules (IFR) activities currently involve approximately 18 million airport operations per year and are forecast by the Federal Aviation Administration (FAA) to increase to about 30 million operations per year by 1993. Most of these operations are conducted by single-pilot crews. The air traffic control (ATC) system expects all aircraft to perform at the same high level. The high IFR accident rate during the approach and landing phase of flight, as documented in reference 1, indicates that the required level of performance has not yet been achieved. It is thought that this level cannot be reached without improvements in aircraft handling qualities, displays, automatic flight control systems, weather information dissemination, training, and ATC procedures.

The approach and landing is normally the phase of IFR flight with the highest work load. The pilot must navigate with greater precision than during the departure or en route phases. Air traffic control communications and frequency changes are more numerous. The pilot must make frequent changes in aircraft altitude, heading, speed, and configuration while approaching the ground. Checklists must be accomplished and navigation charts frequently referred to. The pilot is in a highly dynamic situation

with a high potential for mistakes and has limited time to detect and correct any errors. A successful arrival depends on the correct interpretation of approach chart details, the correct setting of numerous cockpit controls, and precise aircraft guidance near the ground.

Automation in the form of an autopilot has been used to reduce pilot work load and improve pilot performance in the terminal area. Research studies (ref. 2) and airplane accident and incident reports suggest, however, that the probability of pilot error actually increases with an increase in automation, partially because of design limitations of the pilot-machine interface. Conventional autopilot interfaces provide the pilot with many opportunities to make errors because of the requirements to change radio frequencies and autopilot modes as the approach progresses.

The automatic terminal approach system (ATAS) was developed to study ways of significantly reducing the likelihood of pilot error and the work load during terminal area operations by improving the pilot-machine interface. Elements of the ATAS are instrument approach data storage, automatic radio tuning, autopilot, and autothrottle. These elements are used to automatically fly instrument approaches. The ATAS was designed to fly according to the same rules and procedures that the pilot operates by in the present ATC system. An automatic missed approach is executed if the pilot does not assume control at the missed approach point. Finally, the ATAS was designed to accommodate the "real world" requirement of frequent ATC radar vectoring to the final approach course.

A simulated ATAS was developed and a research prototype was built in order to study a concept for improving the pilot interface with high levels of cockpit automation and to evaluate pilot acceptance of such a system. Details of the simulated ATAS design and of its implementation into the Langley General Aviation Simulator are presented in reference 3. A piloted-simulation evaluation of the ATAS was then performed. This report presents the results of an evaluation that involved seven instrument-rated pilots, each flying four instrument approaches with the ATAS and four approaches with the baseline autopilot. The ATAS was well accepted by the pilots and the ATAS runs resulted in lower flight technical error and fewer pilot blunders than with the baseline autopilot.

## Abbreviations and Symbols

### Abbreviations

ADF            automatic direction finder

AKQ	identifier for Wakefield Municipal Airport
ATAS	automatic terminal approach system
ATC	air traffic control
AUTO	ATAS operating mode that uses stored approach data to automatically guide the aircraft
CDI	course-deviation indicator
CRT	cathode-ray tube
DME	distance measuring equipment
ECDI	electronic course-deviation indicator
FREQ	navigation receiver radio frequency
HSI	horizontal-situation indicator
IAF	initial approach fix
IFR	instrument flight rules
ILS	instrument landing system
MANUAL	ATAS operating mode that uses manually input parameters to guide the aircraft
MDA	minimum descent altitude for non-precision approach
MSA	minimum safe altitude
NAV	VOR navigation receiver
NDB	nondirectional beacon
NM	nautical mile
OBS	omnibearing selector
PHF	identifier for Patrick Henry International Airport
SBY	standby mode
VLDS	visual landing display system
VOR	very high frequency omnirange

### Symbols

$h$	airplane barometric altitude
$\dot{h}$	time rate of change of barometric altitude
$V$	airplane airspeed
$\psi$	airplane heading angle

## Test Equipment and Procedures

### Airplane Simulation

The current study was performed using the Langley General Aviation Simulator. This research simulator consists of an enclosed cockpit (fig. 1) interfaced

to a general-purpose digital computer. The cockpit is fully enclosed by the cabin section of a light-airplane fuselage. The simulator instrumentation and avionics are typical of an IFR-equipped high-performance single-engine or light twin-engine airplane. They include an HSI, dual VOR receivers, an ADF, and a two-axis autopilot. An array of speakers provide realistic wind and engine noise up to volumes typical of general aviation airplanes. The control yoke (elevator and ailerons) is hydraulically loaded to provide the appropriate variable force gradients. Rudder-pedal force feel is supplied with springs. This simulator has been used for related studies in automation and displays (ref. 2).

A mathematical model for a typical high-wing, four-seat, single-engine, general aviation airplane was used in the ATAS simulation. This model included changes in flight-control effectiveness and force gradients as a function of airspeed, wing-flap-extension effects, an atmospheric wind-turbulence model, and a radio navigation-aid data base. A landing gear model permitted touchdown and roll-out.

The simulation navigation-aid data base (ref. 4) permits definition of a real navigation environment so that a subject pilot can fly cross-country flights and conduct instrument approaches by using standard instrument charts. This data base includes the location, Morse code audio identifier, and frequency, as applicable, of VOR, DME, NDB, marker beacon, localizer, and glide-slope transmitters.

The simulator is interfaced with a graphics computer and a visual landing display system (VLDS). The graphics computer provides the capability to simulate advanced displays or alphanumeric data on cockpit cathode-ray tubes (CRT's). The VLDS uses a 1:750 scale terrain model and a closed-circuit television to provide an out-the-windshield view during approach and landing. Realistic cloud-breakout and low-visibility effects are also provided.

### Experimental System

The ATAS concept was designed to manage an airplane autopilot, an autothrottle, and navigation radios for the pilot during an instrument approach from terminal area entry to the missed approach point and, if necessary, through the missed approach. The ATAS performed this management task on the basis of stored instrument approach data for each of the approaches to be flown. The purpose of this ATAS was to provide a means to study a concept for improving the pilot interface with high levels of cockpit automation. This interface improvement concept was intended to reduce the number of avionics system

inputs (i.e., navigation radio tuning and autopilot mode changes) and the throttle control required of the pilot during an approach, to improve situational status feedback to the pilot, and to reduce the possibility that pilot distraction or chart misinterpretation could cause a deviation from the correct flight path. This section briefly describes the experimental hardware and its operation. The ATAS hardware, software, and operation are described in detail in reference 3.

The additional simulator hardware required for the ATAS simulation consisted of a control panel located above the existing autopilot controls. (See figs. 2 and 3.) Pilot input to the ATAS consists of an off-standby-on switch, push buttons to engage go-around and holding pattern features, automatic-manual mode-select push buttons for course and altitude guidance, course- and altitude-select knobs, and an on-off push button and a speed-select knob for the autothrottle.

Output of information to the pilot is presented on a CRT (fig. 4). Areas along the left edge of the CRT show the status of the course and altitude modes (automatic or manual), the commanded course and altitude, the autothrottle status, and the commanded airspeed. Areas along the top of the CRT illuminate to indicate when the go-around or the hold function is selected. The remaining area of the CRT displays an electronic course-deviation indicator (ECDI) and five lines of alphanumeric text. These lines of text indicate the progress of the approach (e.g., beginning descent, final approach, or entering holding pattern), altitude deviations, direction and distance to the airport, the current autopilot status, and the name of the approach for which data are stored.

Operation of the off-standby-on switch controls the state of the ATAS and its interface with other simulated aircraft systems. The standby state is intended to be used to enter approach data prior to entering the terminal area. Since this study was concerned with terminal area use of ATAS, no provisions for approach data entry were made and the standby state was not evaluated. Figure 5 shows the interface between the ATAS and other cockpit systems when the ATAS is switched on. In this state, the ATAS controls the tuning of the ADF, the DME, and the NAV 1. The positions of the autopilot mode-select knob and the HSI heading bug are ignored in this state. This was not the desired method of handling the mode-select knob and heading bug, but rather was a compromise required by the simulation hardware.

When the ATAS is turned on, the course and altitude functions are activated in manual mode at the actual heading and altitude. If the autopilot

heading channel is off, then the indicated heading on the ATAS display tracks the airplane heading and movement of the course knob has no effect. If the autopilot heading channel is on, then the heading indicated on the ATAS display is the airplane heading at the moment the ATAS was switched on; the course knob can be used to dial in new headings, and the ATAS commands the autopilot to follow the indicated heading. The ATAS altitude function follows the same rules as the course function for altitude initialization and autopilot interaction. At the moment that both the ATAS and the autopilot altitude channel attain on-status, the airplane altitude is latched into the ATAS display and held by the autopilot. The pilot may then dial a new altitude with the ATAS altitude-select knob, and the airplane will go to that new altitude.

When the course and altitude functions are in the manual mode, the airplane maintains pilot-commanded headings and altitudes. The pilot switches course and altitude between manual and automatic modes with the mode-select push buttons. The automatic mode commands the ATAS to use the stored approach data and internal logic to complete the approach. The pilot may put the course function in automatic mode, provided the autopilot heading channel is on and the approach data have been stored. The altitude function may be placed in automatic mode, provided the course function is in automatic mode and the autopilot altitude channel is on. If the pilot attempts to place either function in the automatic mode when the required conditions are false, then no action or warnings take place. If the course function is switched from automatic to manual mode, then the altitude function also reverts to manual mode. This software interlock between the course and the altitude is designed to prevent undesired climbs or descents while the airplane is being vectored near or across published approach segments.

The go-around button above the CRT can be used to instruct the ATAS to discontinue descent while on the final approach course. Pressing this button while on final approach illuminates an annunciator on the CRT (fig. 4) and stops the airplane descent. The airplane then proceeds to the missed approach point and executes the missed approach procedure. Pressing the go-around button while not on final approach produces no effect.

The hold button is used to instruct the ATAS to enter the next published holding pattern along the airplane flight path. When this mode is selected, an annunciation illuminates on the CRT. Pressing the button when the mode is on turns the mode off and inhibits holding-pattern entry.

The autothrottle is activated by pressing the on-off button and dialing in the commanded airspeed in knots. At the moment that the autothrottle is activated, the actual airspeed of the aircraft is latched as the commanded speed. This prevents any throttle transients upon activation. The autothrottle can be shut off by pressing the on-off button again, by turning the ATAS off, or by manually moving the throttle level to the idle position.

Both the hold mode and the autothrottle are automatically switched on by the ATAS at the beginning of a missed approach. This enables the ATAS to enter the missed approach holding pattern without further pilot input and prevents the airplane from slowing to a dangerously low airspeed as the climb is begun. The pilot can turn the modes off again if desired.

Several compromises were necessary in the implementation of the ATAS in the simulator. The throttle in the cockpit was not back-driven by the autothrottle system because of the absence of servos. An autothrottle term was simply added to the throttle position term in the software when the autothrottle was on. Also, the simulator was equipped with radio controls with mechanical drum-type frequency displays that had to be manually moved. It was, therefore, necessary for ATAS radio tuning to be simulated in the software by ignoring the manually selected radio frequency. This was compensated for by displaying the ATAS-selected navigation frequency with the ECDI on the ATAS CRT. Finally, the heading bug and the course select on the HSI could not be servo driven. This was compensated for by also displaying the ATAS-selected heading and course on the CRT.

## Experiment Design

The study used seven instrument-rated pilots with total flight times ranging from 250 to 7000 hr. The average total flight time was 2074 hr. A professional test pilot and several instrument flight instructors were included in the population. Table I lists the flight experience of each pilot.

Each pilot was required to fly 2 hr of practice approaches with the ATAS prior to any data runs. More practice was allowed if requested. The data runs consisted of eight instrument approaches for each pilot. The nondirectional beacon (NDB) approach of figure 6 was used for four runs and the instrument landing system (ILS) approach of figure 7 was used for the other four runs. Two levels of autopilot complexity were used. In four runs (two NDB runs and two ILS runs), a baseline mode was used wherein the pilot flew the simulator in the longitudinal axis

and a heading-select lateral autopilot mode was engaged. The other four runs flown by each subject used the entire ATAS system. The baseline heading-select autopilot mode was chosen because, of the five levels of autopilot complexity tested in reference 2, it made the largest difference in decreasing work load.

The NDB and ILS approaches were each flown with two different weather conditions as viewed on the outside visual scene. One weather condition was above the published minima for the approach and would allow visual breakout and landing provided the approach was properly executed. The other weather condition was below the published minima and was designed to cause a missed approach to be executed. Table II shows the published minima for the two approaches and the ceiling and visibility values used for the above- and below-minima conditions. No turbulence or wind was used in this study.

Each pilot flew the eight possible combinations of approach type, autopilot level, and weather. Each pilot flew these approaches in a different sequence. Table III shows the sequence of runs for pilot A.

A realistic ATC environment was simulated for the data runs. A remote X-Y plotter was labeled with runway, navigational aid, and approach path positions as well as locations where ATC vectors or altitude assignments should be given. A pseudocontroller watching the airplane ground track in real time, and talking to the pilot by intercom, provided ATC interaction with the pilot.

Each pilot was required to perform a side task in addition to the instrument approach task. The subject was given an E6B-type (circular slide rule) flight computer and asked to solve time-speed-distance problems. The subjects were told to solve the problems at their own pace and not to allow the side task to interfere with the primary task. The same intercom system used to simulate the ATC communications was used to give side-task problems to the subject and to record results. At the subject's request, speed and distance for a problem were given. The subject reported the resulting time verbally.

Data collected included side-task results by phase of approach, X-Y and X-Z plots of airplane path, pilot comments, researcher observations, strip-chart time histories of airplane Eulerian angles, altitude, vertical speed, airspeed, ILS deviations, and printouts of airplane position and autopilot-ATAS states. The state printouts were triggered by changes in approach phase, by changes in autopilot mode, or by pilot inputs to the ATAS.

## Results

The data analysis primarily examined pilot blunders, pilot side-task measures, and pilot comments.

The pilot blunders consisted of large flight-path deviations or researcher-observed errors in the operation of ATAS or autopilot controls.

### **Pilot Blunders**

Pilot blunders were made during both the ATAS runs and the baseline heading-select autopilot runs. Fewer pilot blunders were made during the ATAS runs (11) than during the baseline runs (19). Two factors were predominant in the blunders committed with the ATAS. Of the 11 ATAS blunders, 9 involved "mode errors" or a lack of awareness of the present ATAS mode state or particular mode interactions. An example of a mode error is an attempt to select an automatic ATAS mode while the autopilot is off. Another example of a mode error is shown in figure 8. In this case the altitude mode was in manual and the airplane was approaching the AKQ NDB from the southeast (fig. 6) when the pilot dialed in a new altitude to begin a descent. During the descent, the pilot selected the automatic mode to begin an automatic approach. In this situation, with the airplane not yet established on a published approach segment, the ATAS logic will maintain the existing altitude. Rather than continue down to the pilot-selected altitude, the ATAS stopped the descent. The pilot reselected the manual altitude mode, reentered the desired altitude, then reselected the automatic mode. This cycle repeated until the airplane passed the NDB and was, therefore, established on a published approach segment. Switching to the automatic mode then had the desired effect of causing descent to the initial approach altitude.

The second predominant factor in the ATAS pilot blunders was a lack of awareness of the airplane state or flight path. This was involved in four of the ATAS pilot blunders. Examples include the pilot forgetting to retract the wing flaps during an ATAS-executed automatic missed approach, and the pilot dialing in a heading of 060° on the ATAS when ATC gave a vector of 160°. The error had to be called to the attention of the pilot by ATC.

The 19 blunders during the baseline runs primarily involved 3 factors. The first factor, a lack of airplane or positional situational awareness, was involved in 11 blunders. Examples include turning the wrong direction in a holding pattern, flying through the localizer path and failing to intercept it, inadvertently descending below decision height and landing with cloud ceiling below minima, and failing to descend promptly on a NDB final approach which resulted in a missed approach. The second factor, misinterpretation of navigation instrument indications, was a factor in seven of the blunders. Examples include momentary misinterpretation of the

ADF indicator during NDB approaches and misinterpretation of the HSI while holding on a localizer back course. The third factor, input error, was present in three of the blunders. Examples include mistuned navigation radios and commanding a turn in the wrong direction when the autopilot heading bug was used to make turns of 180°. One of the baseline-run pilot blunders involved misinterpretation of the instrument approach chart.

### **Pilot Side-Task Measures**

The pilots were given a self-paced side task in an attempt to determine the relative work load between the ATAS and baseline runs. The side task was to solve time-speed-distance problems with a circular slide-rule-type computer. The problems were given verbally upon pilot request and the answers were reported verbally by the pilot.

Figure 9 shows the means and the standard deviations of the total number of correct answers given by all pilots as a function of initial or final approach, ATAS or baseline data run, and NDB or ILS approach. Initial approach is defined as the entire data run prior to intercepting the final approach course. The final approach is that portion of the data run after interception of the final approach course and terminates at landing or at the beginning of a missed approach. The number of correct side-task answers cannot be compared directly between the NDB and ILS runs because of the different times required to fly the different path lengths, but comparisons between baseline and ATAS runs are valid. The side-task measure did not discriminate a difference in work load between use of the baseline autopilot and the ATAS.

### **Pilot Comments**

The pilot comments were interpreted with respect to the ATAS controls, the ATAS display, and the pilot interaction with ATAS operating procedures. The control-related comments were further divided into the physical operation of the given controls and the way the controls were integrated with the autopilot. The only problems with the physical operation of the controls were related to the scaling of the course- and altitude-select knobs and to the placement of the controls. The course-select knob changed the course 360° for each revolution of the knob. This was judged to be too sensitive and made accurate setting of headings difficult. The altitude-select knob changed the selected altitude 400 ft for each revolution. This rate was judged to be too small and made setting new altitudes time consuming. Finally, placement of the knobs to the left of the display caused the pilot's right hand to obstruct the

view of the display when the course-, altitude-, or speed-select knobs were used.

With respect to the integration of the ATAS controls, numerous comments indicated that the ATAS and autopilot controls should be integrated into one system rather than be designed as two separate units. One pilot suggested putting an "ATAS" position on the autopilot mode-select knob. Related comments suggested that the HSI heading bug, which is a component of the basic autopilot but is not a component of ATAS, be servo-driven to correspond to the heading selected with ATAS controls. As presently implemented, the pilots used different controls to control a given parameter, such as heading, depending on the level of automation used.

The display-related comments indicated that sufficient information was present to maintain awareness of the progress of the approach, but as the system is implemented, more information concerning the operation of the avionics would be helpful. The pilots believed that the constant display of distance and direction to the airport was beneficial. One pilot indicated a preference for displaying direction from the airport rather than direction to the airport. Another pilot indicated that all the necessary information was present. This comment was corroborated by two incidents during data runs when the ATAS failed. In each case the pilot quickly detected the failure, disengaged the ATAS, and continued the flight without apparent difficulty. Other pilot comments indicated a desire for additional information. Examples include display of the time to airport, annunciation of intersection passage, indications that a valid navigation signal is being received, and an indication that the final vector to an ILS will intercept the localizer. With respect to the operation of the avionics system, the comments indicated that more prompting was needed to assist the pilot. For example, as implemented, if the pilot attempted to select an automatic ATAS mode with the autopilot off, the ATAS simply ignored the input. The pilots indicated that in this instance the ATAS should have advised the pilot that the autopilot was off. Finally, one pilot expressed a concern that putting too much information on the CRT may draw the pilots' attention away from the basic flight instruments.

With respect to pilot interaction with ATAS operating procedures, the pilots commented on the AUTO-MANUAL mode labeling and operation. Some comments indicated that the labels AUTO and MANUAL were confusing. Some questioned whether MANUAL was to be used for manual flying of the airplane or for manual operation of autopilot controls. It was actually for manual input, on the ATAS panel,

of headings, altitudes, and speeds to fly. Likewise, comments indicated that the meaning of the AUTO label was not obvious. One pilot, in fact, occasionally selected the AUTO mode in an attempt to automatically fly a heading that had been manually dialed in on the ATAS panel.

Regardless of the mode labeling, the pilots indicated confusion about the operation of the modes. One pilot indicated uncertainty about when the full automation capabilities should be selected. Another comment indicated that the system worked well once everything was in automatic, but that going from fully manual to fully automatic was awkward. This is consistent with one pilot's request that it be possible to put all modes into automatic with the press of one button.

Pilot comments indicated that understanding the control mode operations was further complicated by a difference in the transition from manual to automatic in the heading and altitude channels. When the heading channel was switched from manual to automatic, it maintained the last heading dialed in until the airplane intercepted a published approach path. The altitude channel, however, when switched from manual to automatic when not on an approach segment, maintained the present altitude regardless of the last altitude dialed in. The pilots indicated that the altitude channel should have operated the same as the heading channel. Implementation of this suggestion would have probably eliminated some of the blunders that occurred (see fig. 8) when the pilot dialed in a new altitude just prior to selecting the automatic mode.

## Closing Discussion

Several important trends can be observed in the data. The higher level of automation both reduced the frequency of pilot blunders and changed the nature of the blunders that did occur. The reduction in the frequency of blunders contradicts the results of reference 2, wherein pilot blunders increased with higher levels of automation. This discrepancy could be due to several factors. The autopilot interface in reference 2 removed the pilot from the normal airplane control loop, but required manipulation of numerous avionics controls as the airplane was maneuvered for the approach. Little feedback concerning the approach or avionics status was provided by that autopilot system. The ATAS also removed the pilot from the airplane control loop. The ATAS then took care of the detailed manipulation of avionics controls, provided approach and system status information to the pilot, and simplified speed control with

the autothrottle. It is possible that the pilots committed fewer blunders simply because they had fewer opportunities to do so.

The change in nature of the blunders committed in this study can be tracked to the different systems that the pilot controlled. With the baseline autopilot, the blunders were mostly associated with lack of navigational situational awareness and with instrument and chart misinterpretation. With ATAS, very few blunders were associated with navigational situational awareness, but instead most were associated with the operation of the various automation modes. It is possible, however, that the pilots' navigational situational awareness was lower with ATAS than without it, but this lack of awareness did not introduce blunders because of the high level of automation.

Probably the most important observation from the data is related to the ability of the pilots to form a "mental model" of system operation. Many of the pilots' comments and blunders indicate problems with the integration of the ATAS with the autopilot and other avionics. Pilots commented that the autopilot and ATAS should be one system. The pilots were sometimes confused about when the ATAS modes should be switched from manual to automatic. Comments were received that more prompts should be provided by ATAS. These comments are all related to the understanding, or mental model, of the system operation.

The adequacy of the pilots' mental model could possibly be improved in several ways. One is to simplify the system that must be learned. In some cases, the input of the same parameter to the ATAS autopilot, such as heading, was made with different controls depending on the level of automation in use. As previously noted, an inconsistency of operation was present with respect to the behavior of the course and altitude features when they were switched from manual to automatic. Integrating the autopilot and

ATAS controls and improving consistency of system operation might simplify the system.

A second way to improve the adequacy of the mental model is with prompting. Prompting would not improve pilot understanding or simplify the system, but it could bridge the gap when system complexity exceeds the pilots' understanding or ability to monitor all aspects of system operation. In this study, suggestions were received that the ATAS provide prompting when certain inappropriate inputs were made.

A third possible, but much less desirable, way to improve the pilots' mental model is through increased training and practice. Pilots must have enough training on a system to understand the basic principles of operation and to learn the operational details and possible "traps" that exist with many systems. Pilot comments about uncertainty of the purpose of the ATAS manual and automatic modes, and related blunders, indicate that more training may have compensated for deficiencies in the ATAS pilot-machine interface design.

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4. Bergeron, Hugh P.; Haynie, Alix T.; and McDede, James B.: *Development of a Computer Program Data Base of a Navigational Aid Environment for Simulated IFR Flight and Landing Studies*. NASA TM-80064, 1980.

Table I. Pilot Flight Experience

Pilot	Total flight time, hr	IFR flight time, hr
A	250	63
B	370	55
C	600	100
D	1600	140
E	1700	400
F	3000	400
G	7000	1500

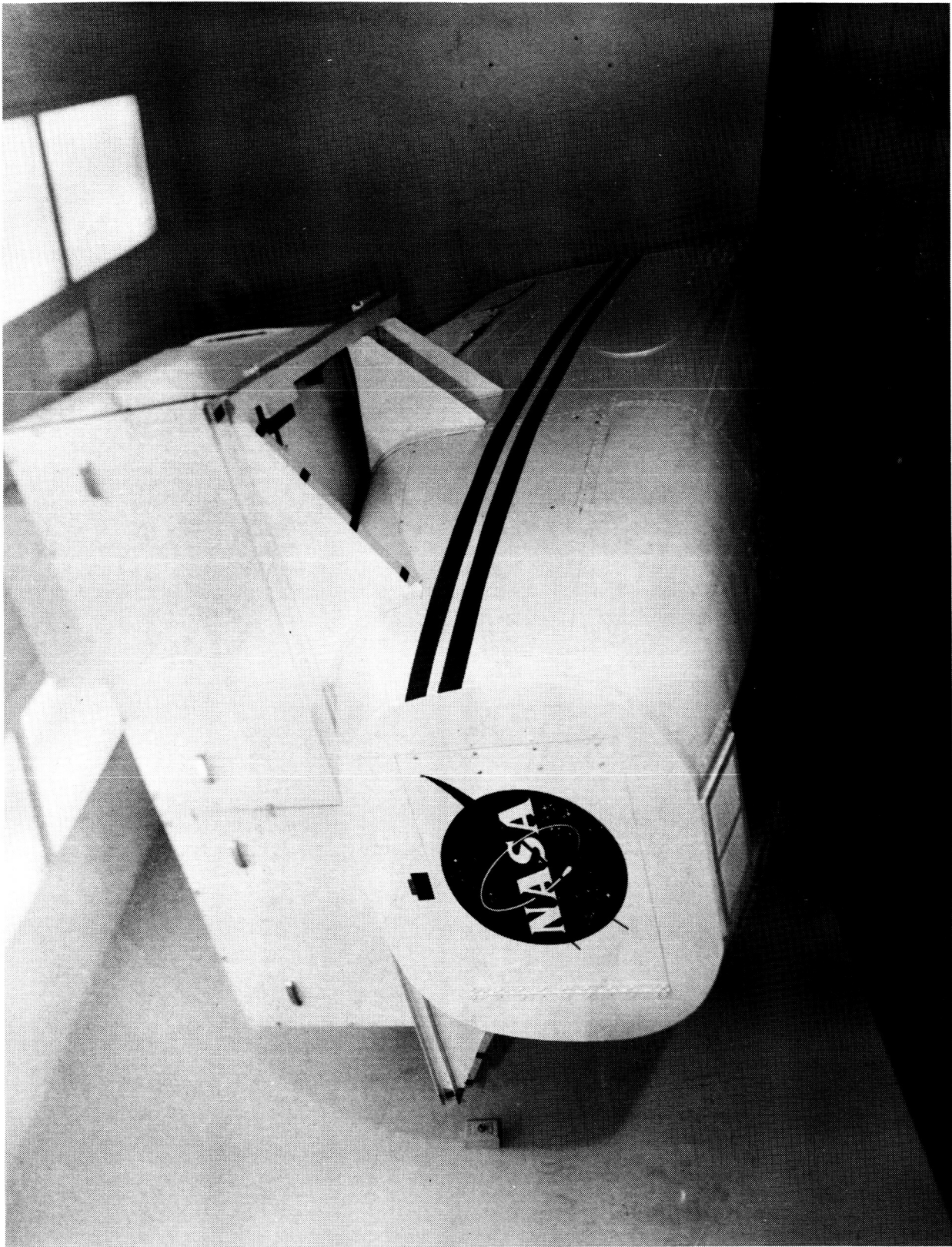
Table II. Approach Minima and Simulated Weather Conditions

Parameter	ILS approach	NDB approach
Minimum ceiling, ft . . . . .	200	727
Minimum visibility, mi . . . . .	0.5	1
Above-minima case-ceiling, ft/visibility, mi . . . . .	300/1.0	830/1.5
Below-minima case-ceiling, ft/visibility, mi . . . . .	110/1.0	630/1.5

Table III. Run Sequence for Pilot A

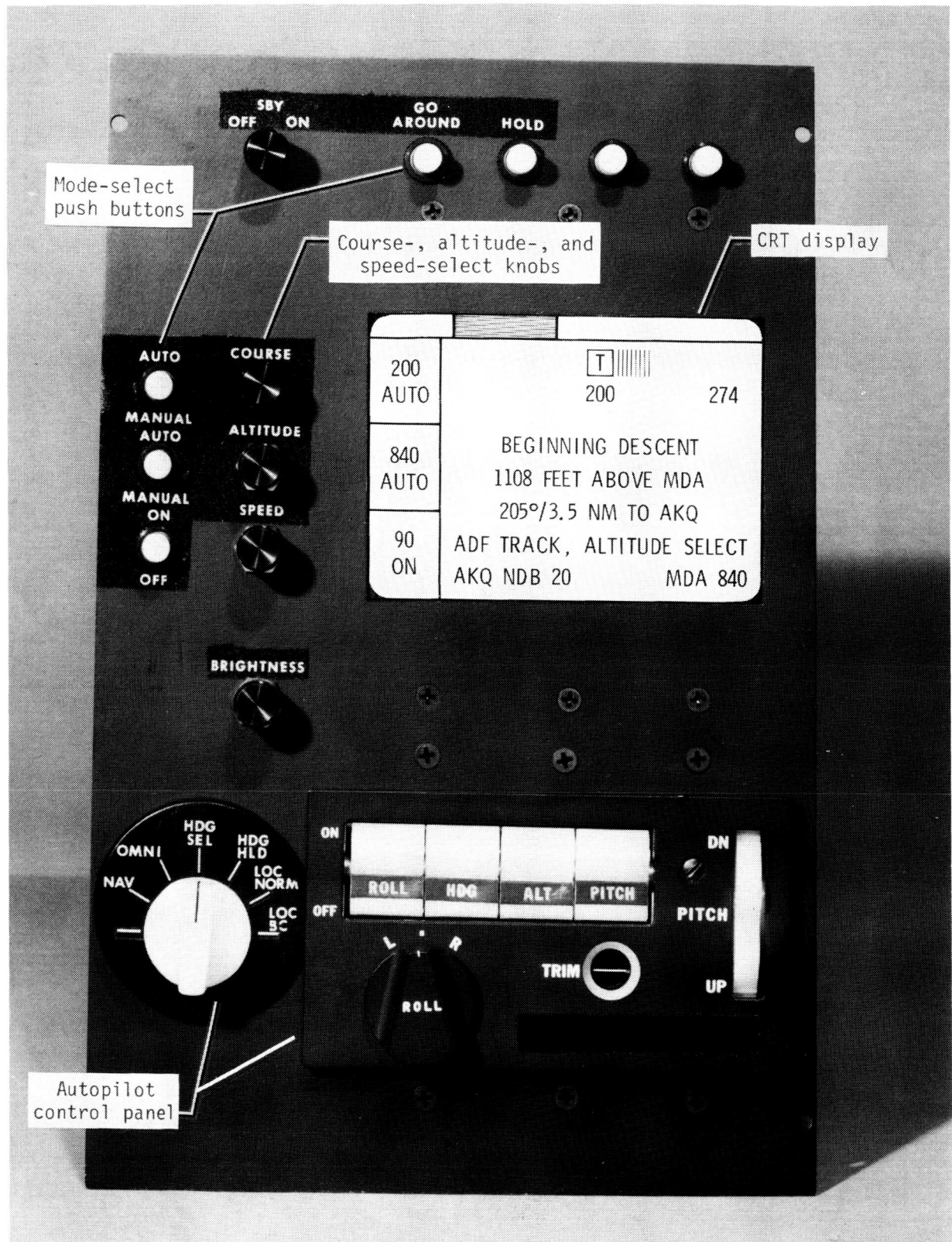
Run number	ATAS state	Approach type	Weather condition relative to minima
1	Off	NDB	Below
2	On	NDB	Above
3	On	ILS	Below
4	Off	NDB	Above
5	On	ILS	Above
6	Off	ILS	Below
7	On	NDB	Below
8	Off	ILS	Above

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Figure 1. External view of cabin of Langley General Aviation Simulator.



L-83-134

Figure 2. ATAS control and display panel.

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Figure 3. ATAS installation in Langley General Aviation Simulator.

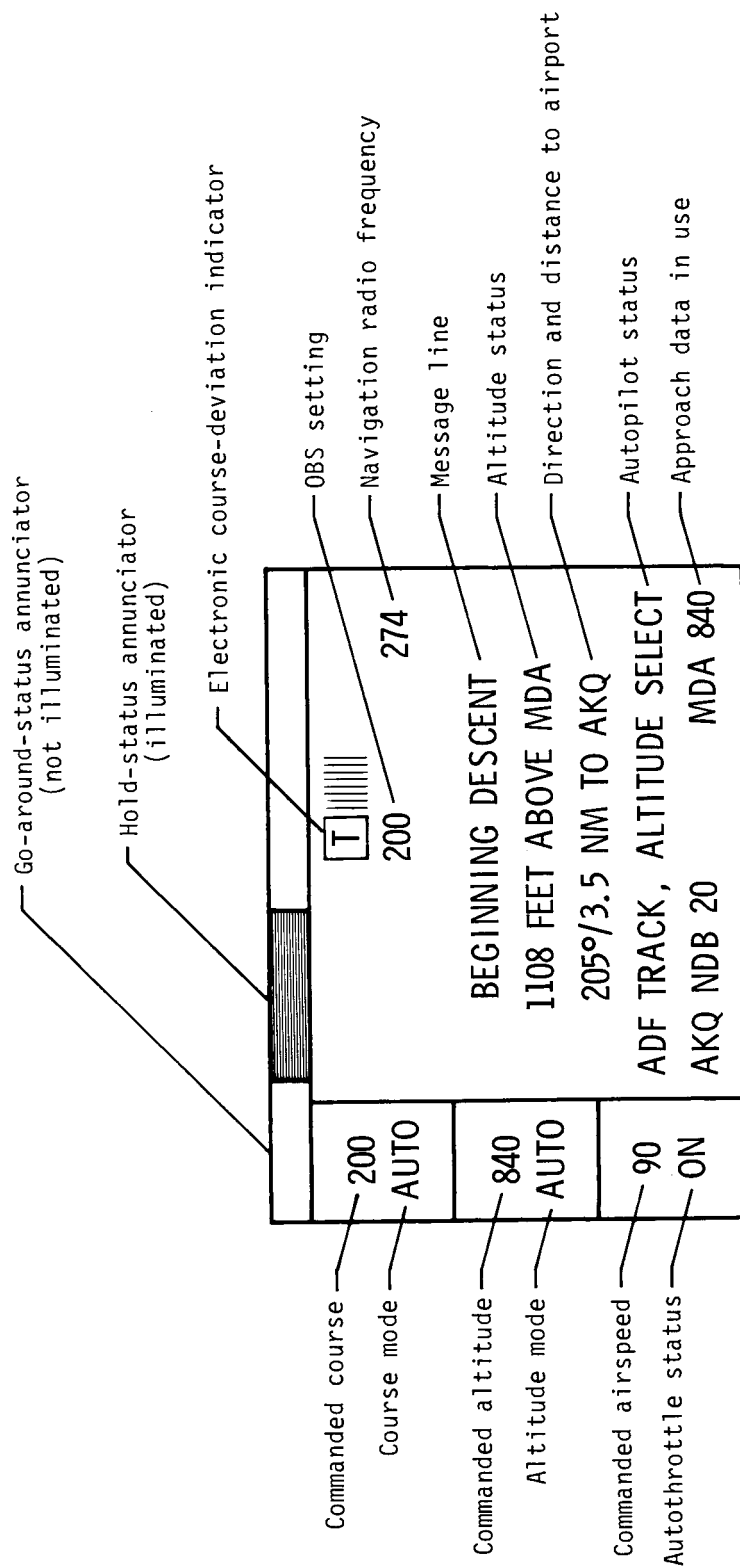


Figure 4. ATAS CRT display.

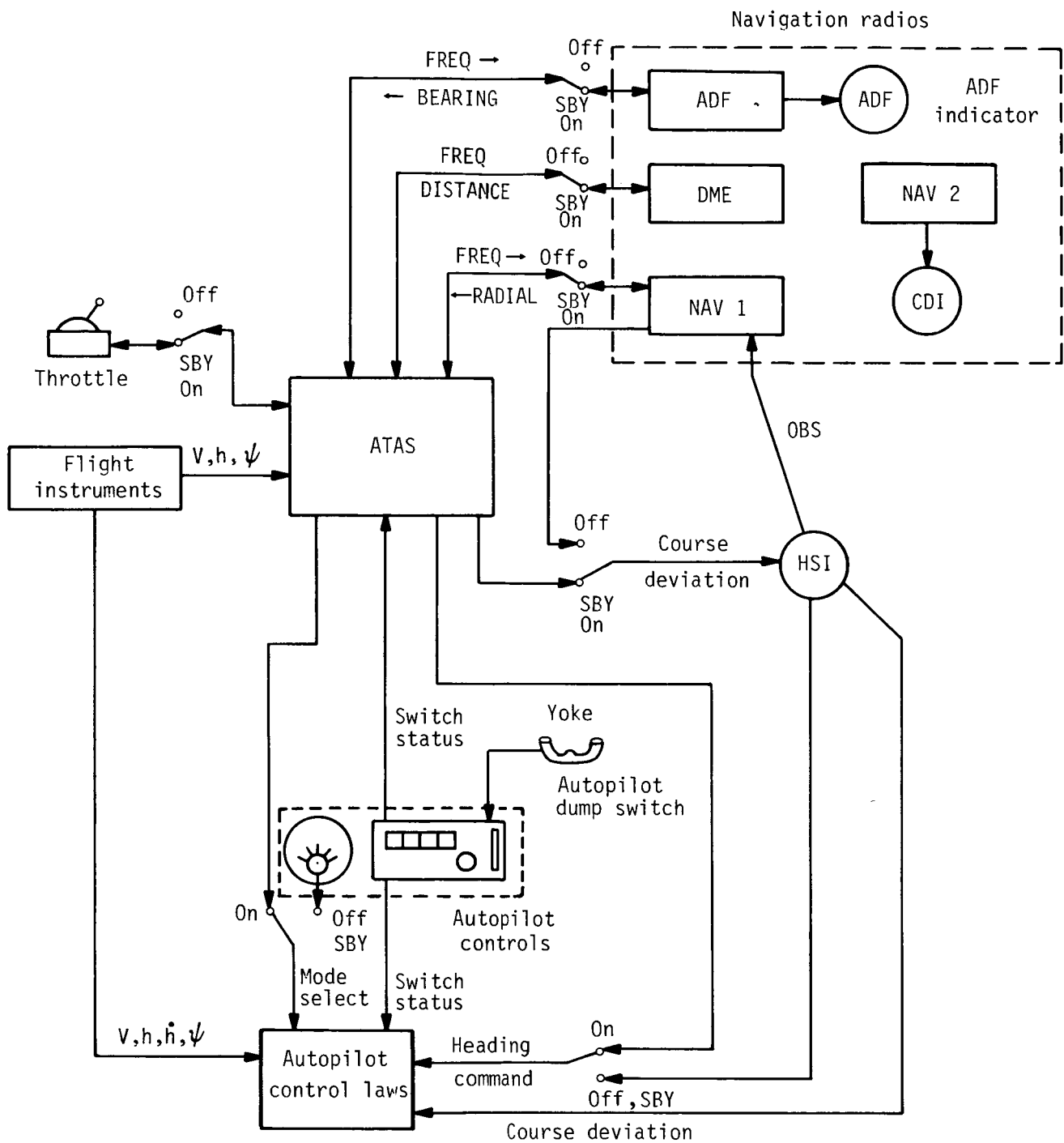


Figure 5. ATAS interface with simulated avionics and instruments.

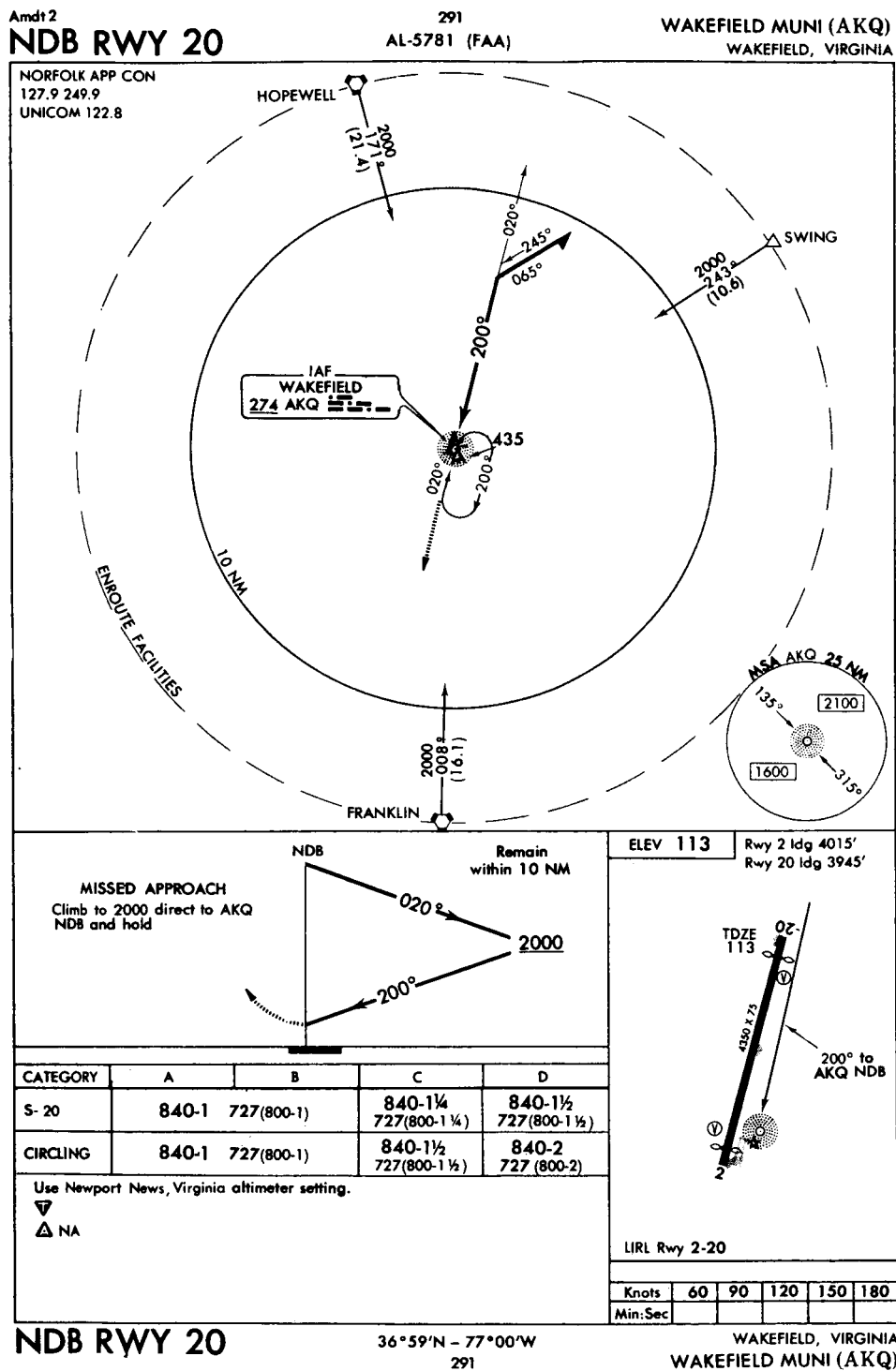


Figure 6. Nondirectional beacon (NDB) approach (runway 20) at Wakefield Municipal Airport.

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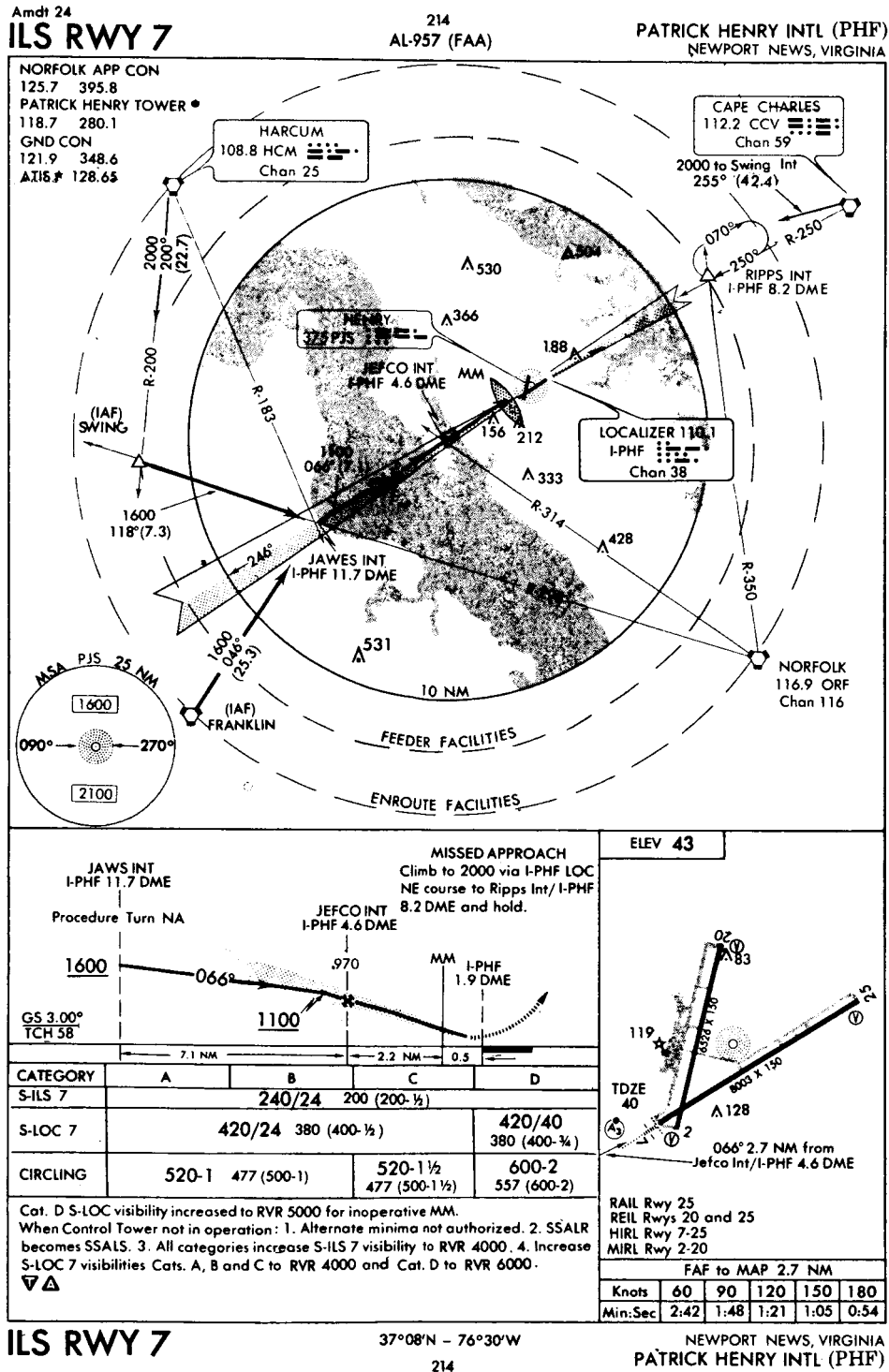


Figure 7. Instrument landing system (ILS) approach (runway 7) at Patrick Henry International Airport.

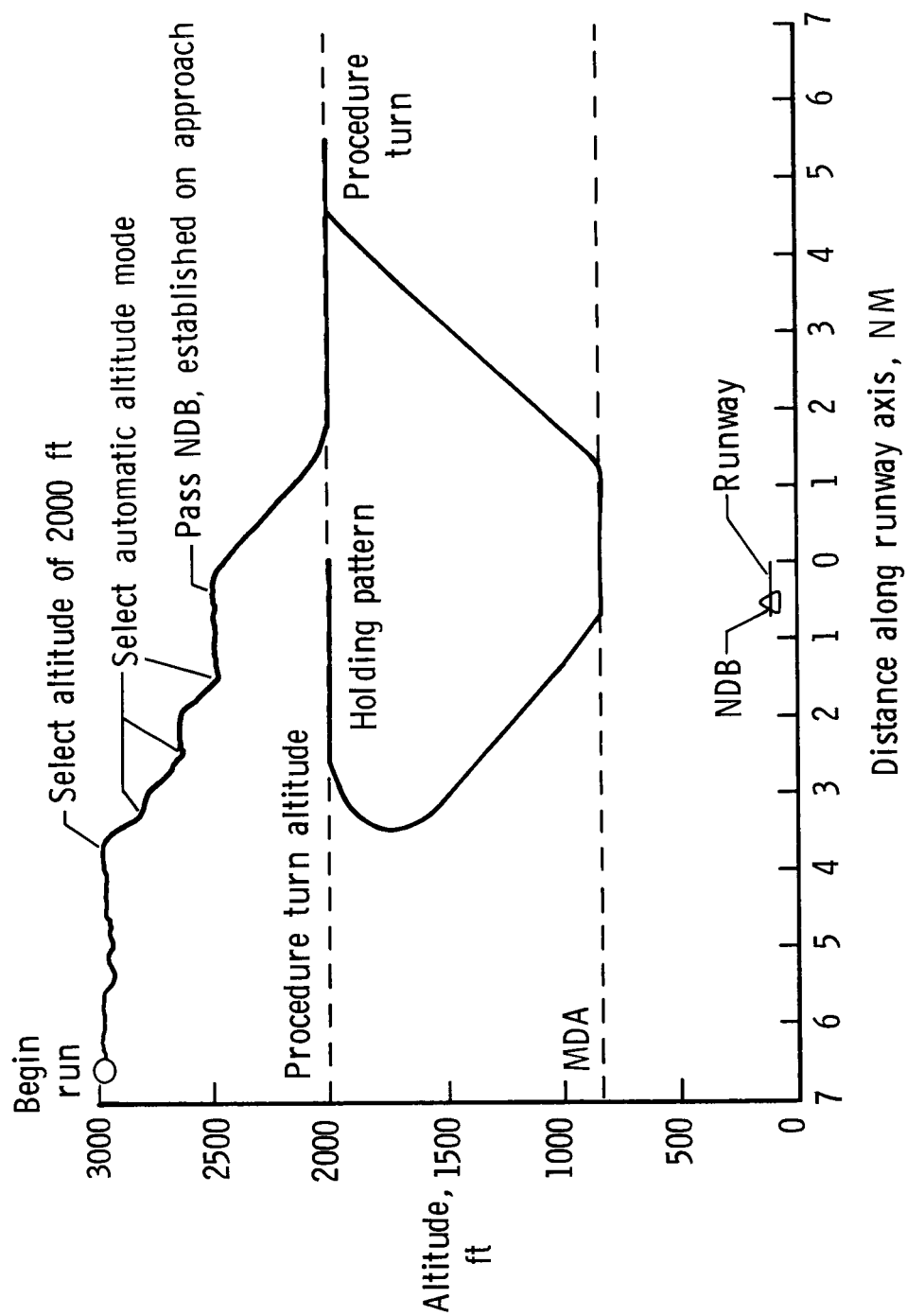
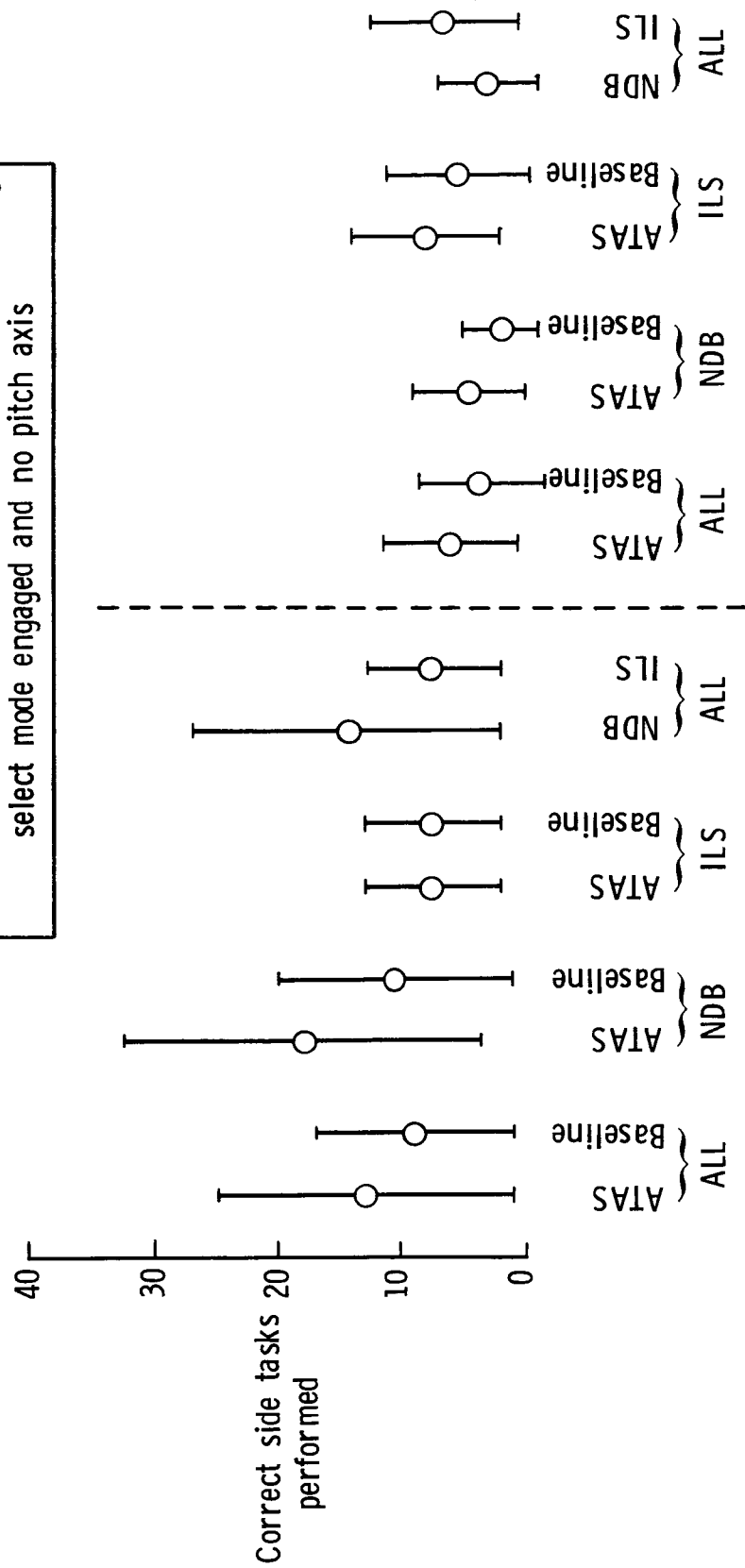


Figure 8. Altitude plot of flight path during incorrect selection of automatic ATAS altitude mode.

Note: Baseline is conventional autopilot with heading-select mode engaged and no pitch axis



(a) Initial segment of approach.

(b) Final segment of approach.

Figure 9. Mean and standard deviations of number of correct side tasks performed.

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16. Abstract <p>Research has identified the pilot-machine interface with cockpit automation as a critical factor in achieving the benefits of automation and reducing pilot blunders. As a means of improving this interface, an automatic terminal approach system (ATAS) was conceived that can automatically fly a published instrument approach by using stored instrument approach data to automatically tune airplane radios and control an airplane autopilot and autothrottle. The emphasis in the ATAS concept is a reduction in pilot blunders and work load by improving the pilot-automation interface. A research prototype of an ATAS was developed and installed in the Langley General Aviation Simulator. A piloted-simulation study of the ATAS concept showed fewer pilot blunders, but no significant change in work load, when compared with a baseline heading-select autopilot mode. With the baseline autopilot, pilot blunders tended to involve loss of navigational situational awareness or instrument misinterpretation. With the ATAS, pilot blunders tended to involve a lack of awareness of the current ATAS mode state or deficiencies in the pilots' mental model of how the system operated. The ATAS display provided adequate approach-status information to maintain situational awareness, but system prompting was desired by the pilots.</p>					
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